Using OMI and TES Radiances to Improve Tropospheric Ozone Profile Retrievals

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Introduction

Worden et al. [1] showed that the vertical resolution of tropospheric ozone profiles can be significantly improved by combining ultraviolet (UV) and thermal infrared (TIR) observations.

- A theoretical study was carried out using a combination of simulated UV and TIR observations in a nadir viewing geometry. The simulated observations matched vertical resolutions of OMI (~12 km) and TES (~ 6 km).
- In the boundary layer, the improvement in the ability to resolve the ozone vertical distribution about a factor of two compared with either instrument alone.
- In the free troposphere, there was a substantial improvement in the vertical resolution of ozone (between 20% and 60%) as compared to the TES vertical resolution.

This study showed the approach and results obtained by combining simultaneously measured OMI and TES radiances in the retrievals to improve the sounding of tropospheric ozone.

TES and OMI Measurements

OMI is a nadir-viewing imaging spectrograph

- Spectral Range 270 – 500 nm
- Spectral Resolution 0.42 – 0.63 nm
- Field of View 114° (swath width 2600 km)
- Number of pixels in the cross track direction
  - UV1 module (264 – 311 nm): 30
  - UV2 module (307 – 383 nm): 60
  - Visible module (349 – 504 nm): 60

TES is a Fourier transform spectrometer

- Spectral Range 3.3–15.4 µm
- Spectral Resolution 0.1 cm^{-1}
- Field of View 0.23°

The OMI, ground pixels which were the most nearly coincident with the TES measurements, were selected as coincident measurements and were used in the combination. Figure 1 shows the geolocations for a set of TES and OMI coincident measurements. They were recorded with a low cloud and aerosol loading conditions over a major ozonesonde launch site. The ozonesonde measurements were made within 1 hour and 25 km of the OMI and TES ground pixels.

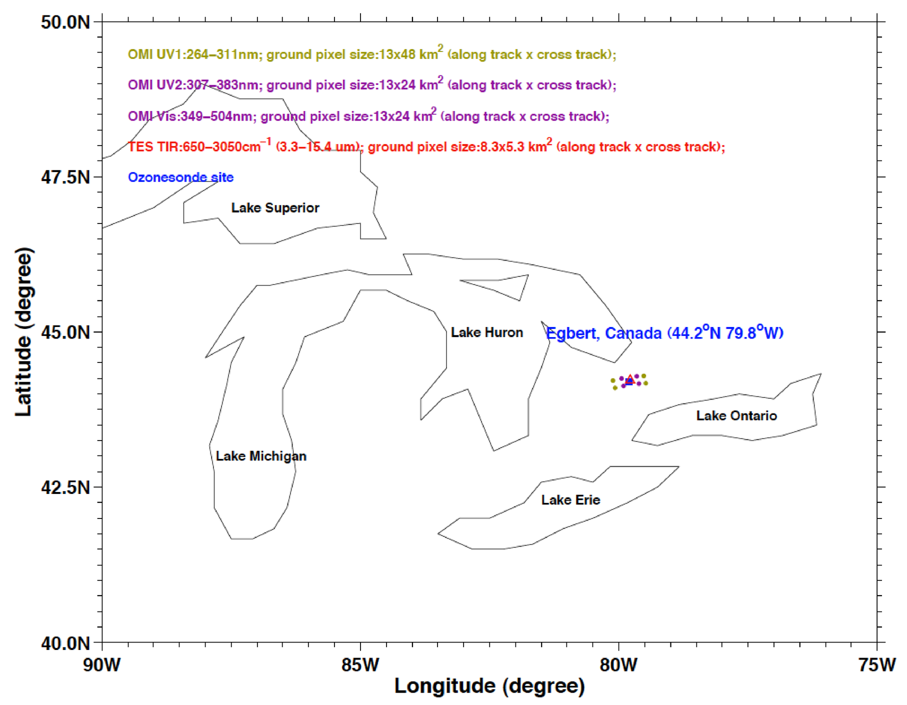

Figure 1 Locations of OMI and TES measurements over Egbert, Canada on July 5th, 2008.

Radiative Transfer Model and Retrieval Methodology

In this work, the core of the forward model uses the linearized vector radiative transfer model VLIDORT [Spurr, 2006] for the numerical computation of the Stokes vector in a multiply-scattering multilayer medium. This model uses the discrete ordinate method to approximate the multiple scatter integrals. VLIDORT has the capability to account for sphericity in the treatments of the incoming solar beam and outgoing beam attenuations. It is able to calculate the Stokes parameters I (only need this component for our application), Q, U and V with given model atmosphere, spectroscopic parameters and viewing geometry. VLIDORT is also fully linearized: along with the radiance field, it delivers analytic weighting functions with respect to any atmospheric and/or surface properties.

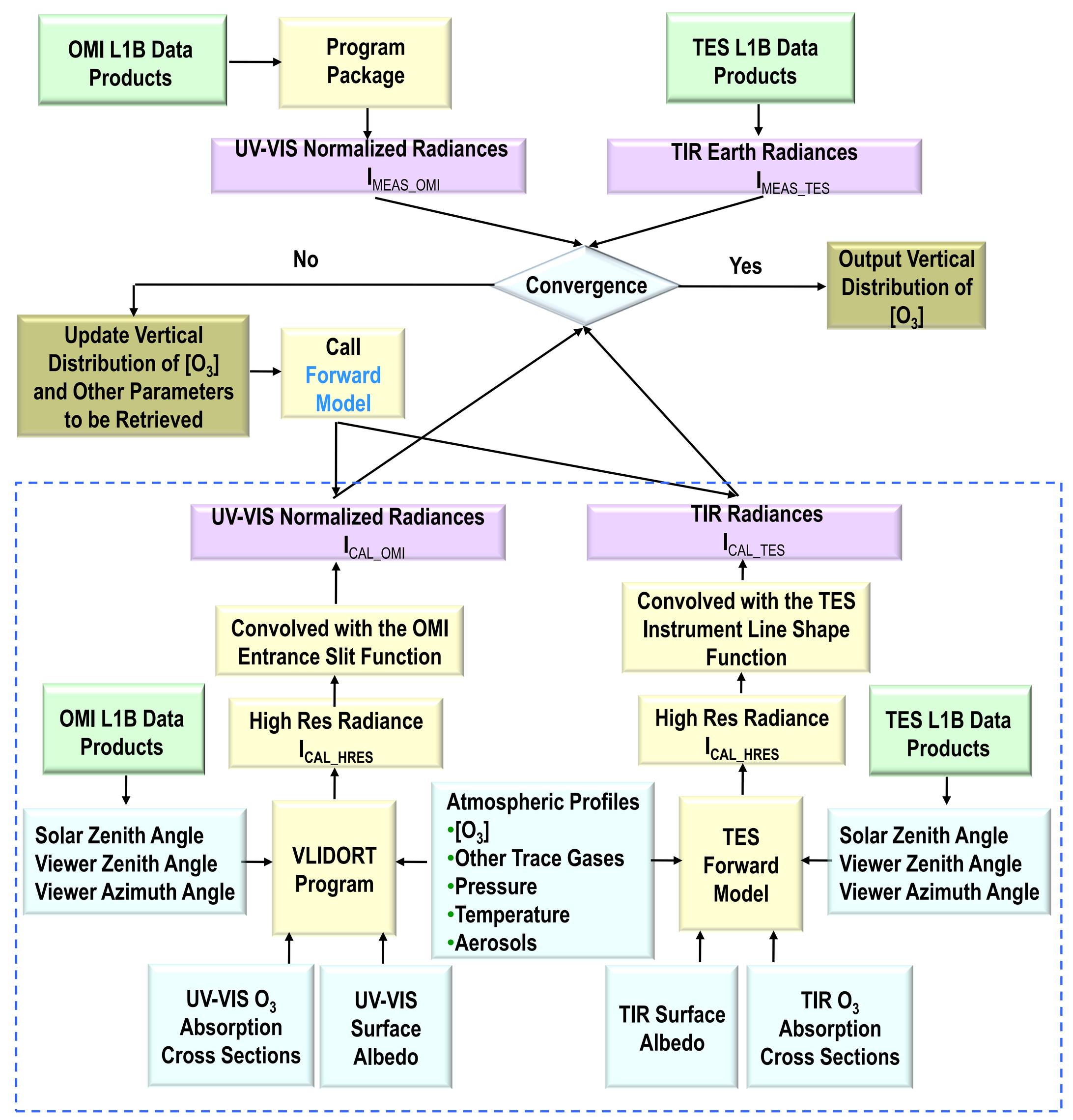

Figure 2 Data processing flow from the measured spectra to the vertical distribution profiles of ozone volume mixing ratio. Forward model is indicated within the blue dash lines.

The standard approach for atmospheric retrievals involves finding the solutions in a moderately linear regime. Our retrieval follows the optimal estimation method by Rodgers [2000]. The Levenberg-Marquardt iteration method suggested by Rodgers [2000] has been written in IDL programming language and was tested in our group. Some necessary format conversions and tests are also being made to the input parameters in order to satisfy the requirements of the data analysis programs. Figure 2 displays the data analysis procedure using recorded spectra to obtain [O_3] VMR distribution as a function of altitude.

The portion in the forward model, which simulates Earth radiances in the TIR spectral region, has been developed and validated previously by the TES retrieval team. The next step is to set up the forward model for the UV-VIS spectral region. The following sections will introduce the progresses and status on this aspect.

OMI Measured Radiances

The OMI L1b data products provides the calibrated Earth radiance and solar irradiance spectra together with quality information and metadata. In addition, the extensive geolocation (e.g., latitude, longitude and altitude of each ground pixel) and ancillary information (e.g., solar zenith angle, and the angles describe the viewing geometry), which are being used the simulations of radiances in the forward model, were included in the L1b data base.

- In the UV spectral region, the solar absorption lines dominate the spectral features. It is a challenge to simulate high spectral resolution solar spectra especially in a broad spectral range. In addition, a scientific instrument always has systematic bias on its measured quantities. Hence, using the normalized radiances in the retrievals helps to simplify forward model and eliminates the systematic bias in the measurements. Figure 3 shows that the ozone absorption features can be clearly seen in the Huggins band spectral regions after removing the solar features.
- Figures 4 – 6 shows the normalized radiances distributions for OMI ground pixels in the cross track direction. They were measured by the OMI instrument on July 5th, 2008. The measurements over Egbert, Canada were made in the swath center with a viewer zenith angle of 9.1554°.

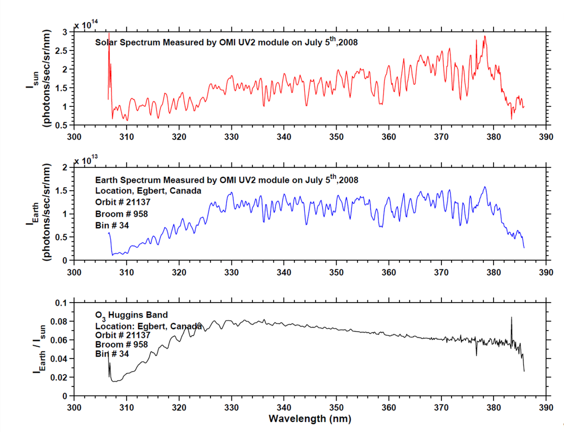

Figure 3 Sample spectra recorded by OMI UV2 module over Egbert, Canada on July 5th, 2008.

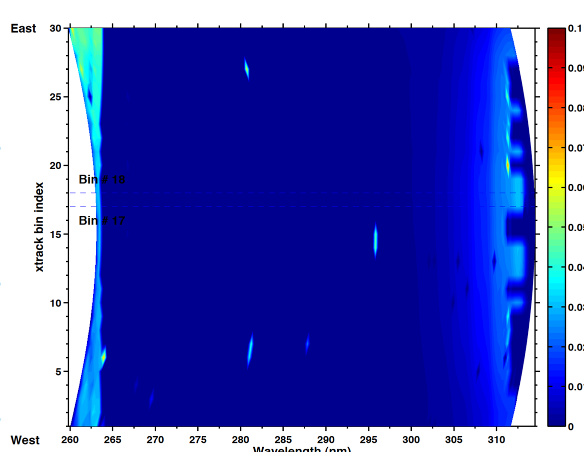

Figure 4 Normalized radiance cross track measured by OMI UV1 module (264 – 311 nm) on July 5th, 2008. The blue dash line indicates the spectrum used in the combination of multiple spectral regions.

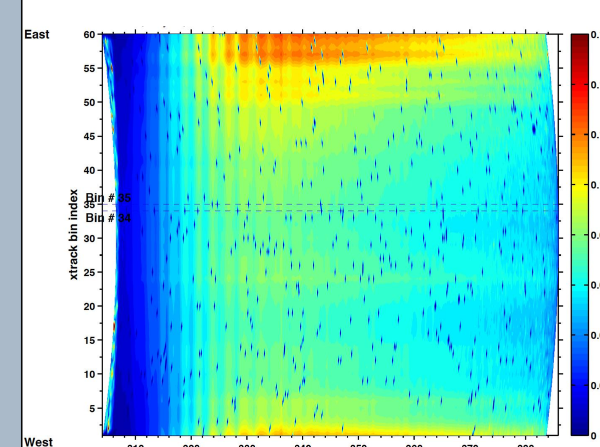

Figure 5 Same as figure 4 but for OMI UV2 module (307 – 383 nm).

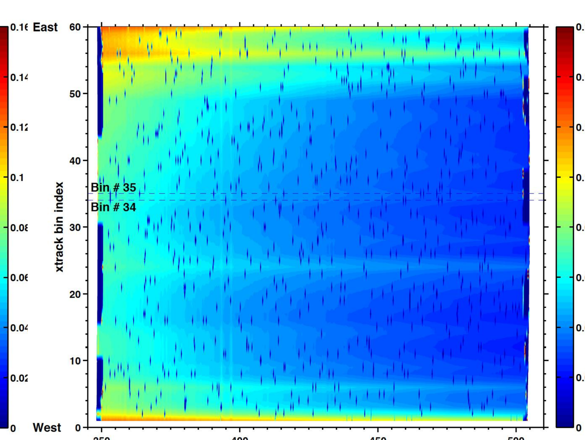

Figure 6 Same as figure 4 but for OMI visible spectral range (349 – 504 nm).

Ancillary Information Used in Forward Model

In order to simulate the radiance accurately, the ancillary information have been collected and used in our study. For example, the global map of Earth surface reflectance climatology data derived from 3 years of OMI data provides the surface albedo in the OMI spectral region [4]. In addition, the spectral slit function needs to be taken into account in the radiance simulation. Dobber et al. [5] characterized the OMI instrument and provided a set of OMI instrument parameters include in the spectral slit function.

Preliminary Results

- Figure 7 shows the radiance simulation for a Rayleigh atmosphere (no aerosols) with Lambertian reflectance assume for the surface. Note the success of forward model account for the details of the ozone Hartley and Huggins bands .
- The disagreement in the part of spectrum is expected since a full retrieval has not been accomplished, which is expected to improve the detailed agreement between measurement and model.

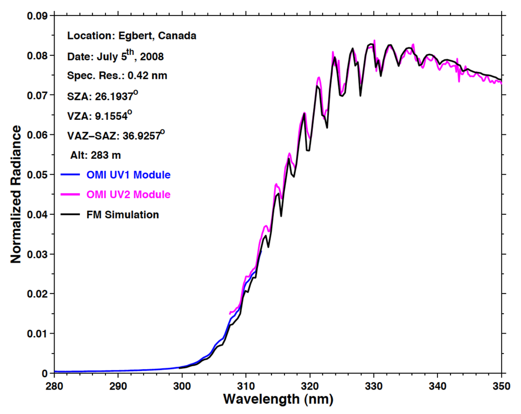

Figure 7 The normalized radiance measured by OMI in the Hartley and Huggins bands over Egbert, Canada on July 5th, 2008.

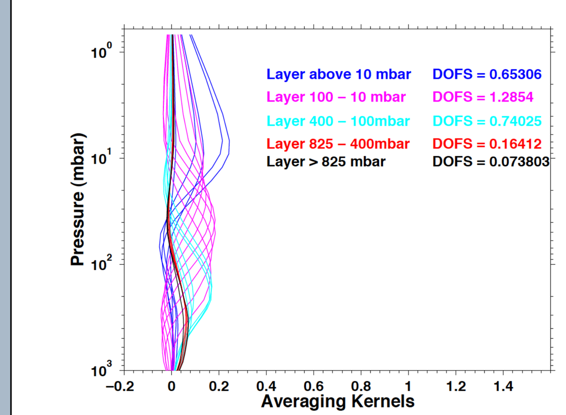

Figure 8 Averaging kernels of combining Hartley and Huggins bands for O_3 profile retrieval at Egbert, Canada.

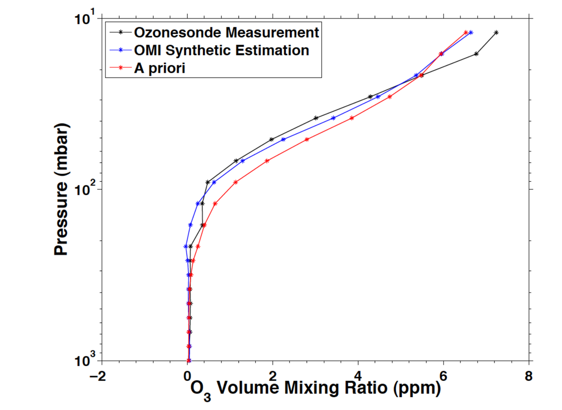

Figure 9 Synthetic ozone estimation for the measurements at Egbert, Canada, is calculated using the linear retrieval method [Rodgers, 2000] .

Summary and Future Work

- An approach to combine the OMI and TES measurements in ozone vertical profile retrievals have been established.
- The forward model has been developed correctly since the model calculation matches the measurements on the normalized radiances.
- Full retrievals need to be accomplished.
- Comparisons on the O_3 VMR vertical distributions will be carried out between the results from combination of TES and OMI measurements and those of ozonesonde measurements.

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